FDTD Modeling of Diffuse Scattering and Transmission at Rough Walls for 5G Communication Systems

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In emerging 5G systems employing frequencies of tens of GHz, the role of diffuse scattering from rough surfaces becomes much more pronounced than in conventional wireless systems, when it comes to calculating link budgets with propagation modeling techniques such as ray-tracing. The conventional approach of accounting for the presence of a rough surface is to modify the standard Fresnel reflection coefficient by a factor attributed to roughness (R. Janaswamy, *Radiowave Propagation and Smart Antennas for Wireless Communications*, pp. 26–29); otherwise, this approach provides no information as to which other diffuse scattering directions may be traced.

The problem of modeling diffuse scattering in wireless channels has been studied even in the context of 900 MHz wireless systems (V. Degli-Esposti, *IEEE Trans. Antennas Propagat.*, vol. 49, no. 7, Jul. 2001), with models that are calibrated with measurements. In computer graphics, this problem has also been studied and given rise to the concept of "bi-directional reflection/transmission distribution functions" (M. Ashikmin et al., *Proc. SIGGRAPH 2000*), which capture the diffuse scattering properties of objects illuminated by a light source. More importantly, this problem is intimately connected to the classical topic of rough surface scattering. Unlike remote sensing studies though, a wireless propagation model should also include estimates of the transmission through rough surface slabs, such as walls, in addition to reflection from those.

To that end, we formulate a finite-difference time-domain (FDTD) model for the oblique incidence of a plane wave on realistic wall models with surface roughness, building on the work of (C.D Moss et al., *IEEE Trans. Geoscience Remote Sens.*, vol. 40, no. 1, Jan. 2002), which focused on scattering from a rough surface. We use our simulations to deduce correction terms for the reflection and transmission coefficients at the wall, used by an image based ray-tracer (N. Sood, C.D. Sarris, *Proc. IEEE AP-S Int. Symp. Antennas Propagat., 2017*) and to identify additional paths that need to be further traced. This hybrid approach is scaleable to realistic channel geometries as it retains the efficiency of ray-tracing, using FDTD to enhance its accuracy in the challenging situation that involves strong diffuse scattering components.